

Towards Measuring Enceladus' Plume Constituents at Hypervelocity

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the Hypervelocity Sampling Team

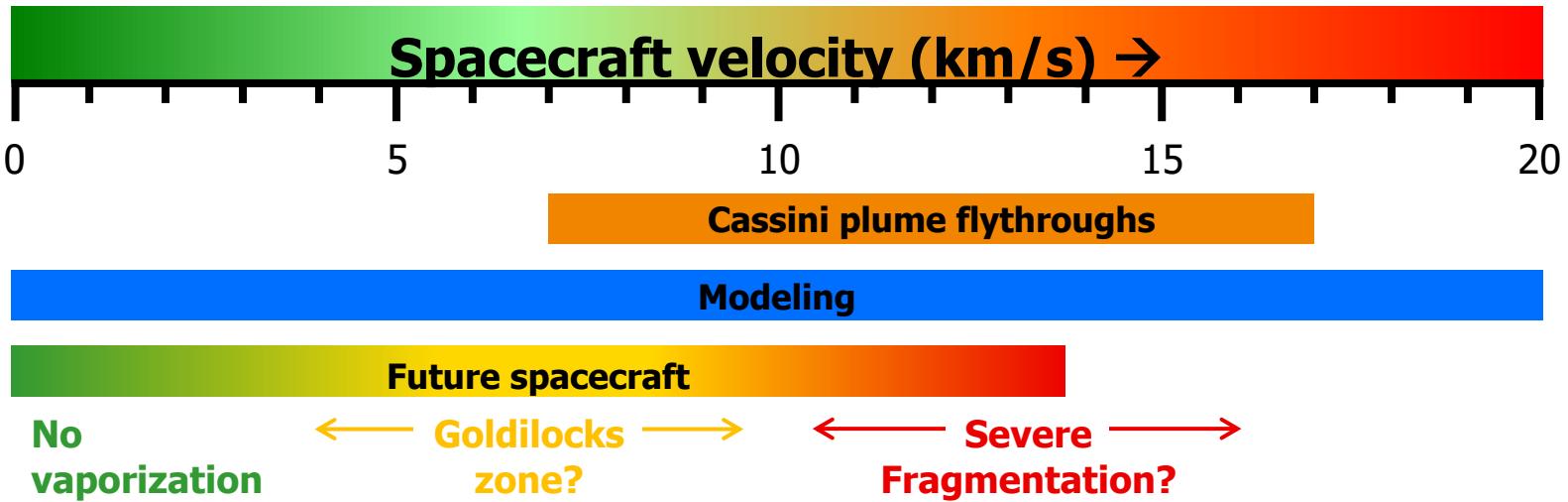
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Jet Propulsion Laboratory
California Institute of Technology

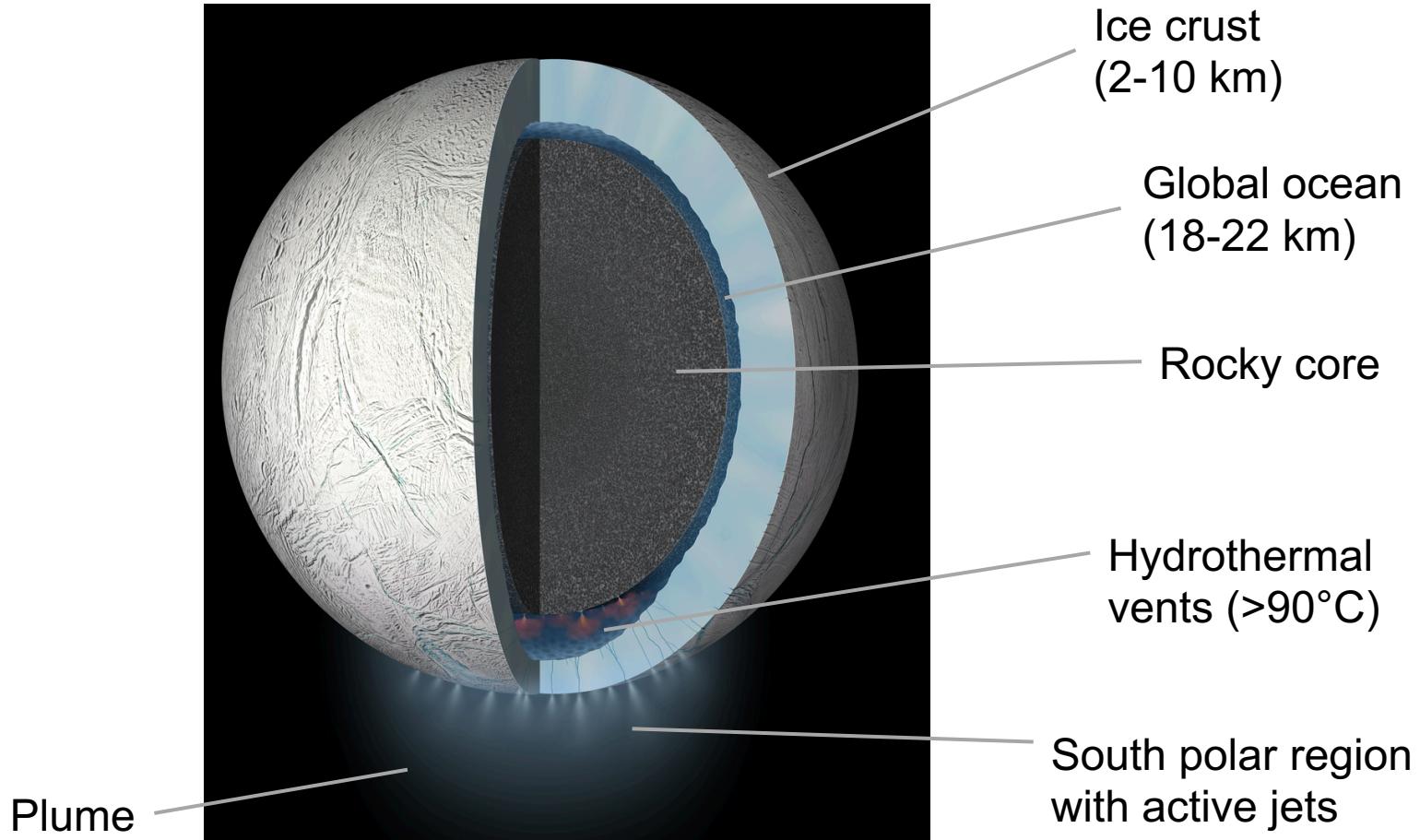
Hypervelocity sampling

- Cassini sampled the plume of Enceladus at hypervelocity (>1 km/s)
- Hypervelocity sampling presents challenges
 - Need to balance volatilizing with fragmentation



There is a need to validate instrumentation and methodologies for future missions utilizing hypervelocity sampling.

Why Enceladus?



Enceladus is one of the prime targets to search for aqueous-based life

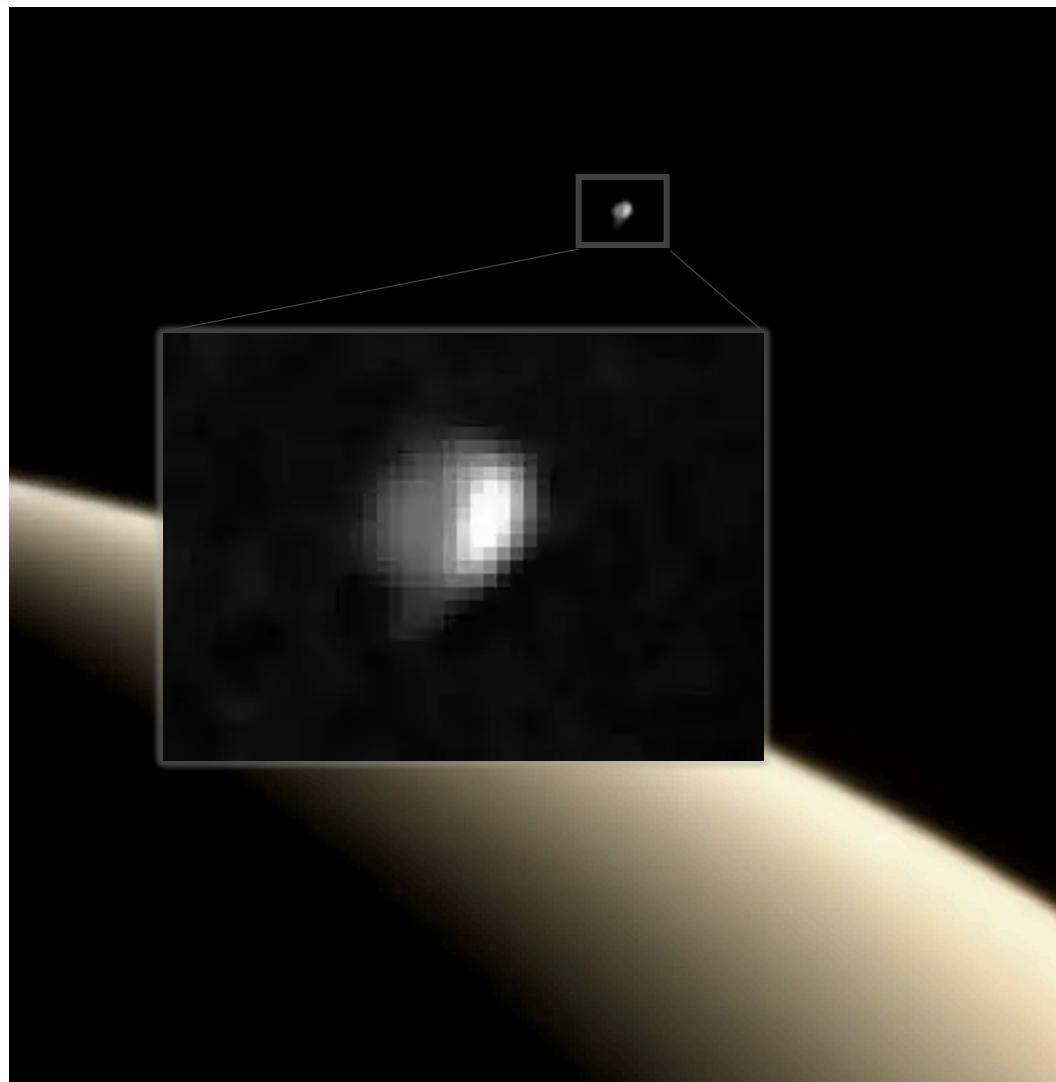
Plume discovery –Cassini



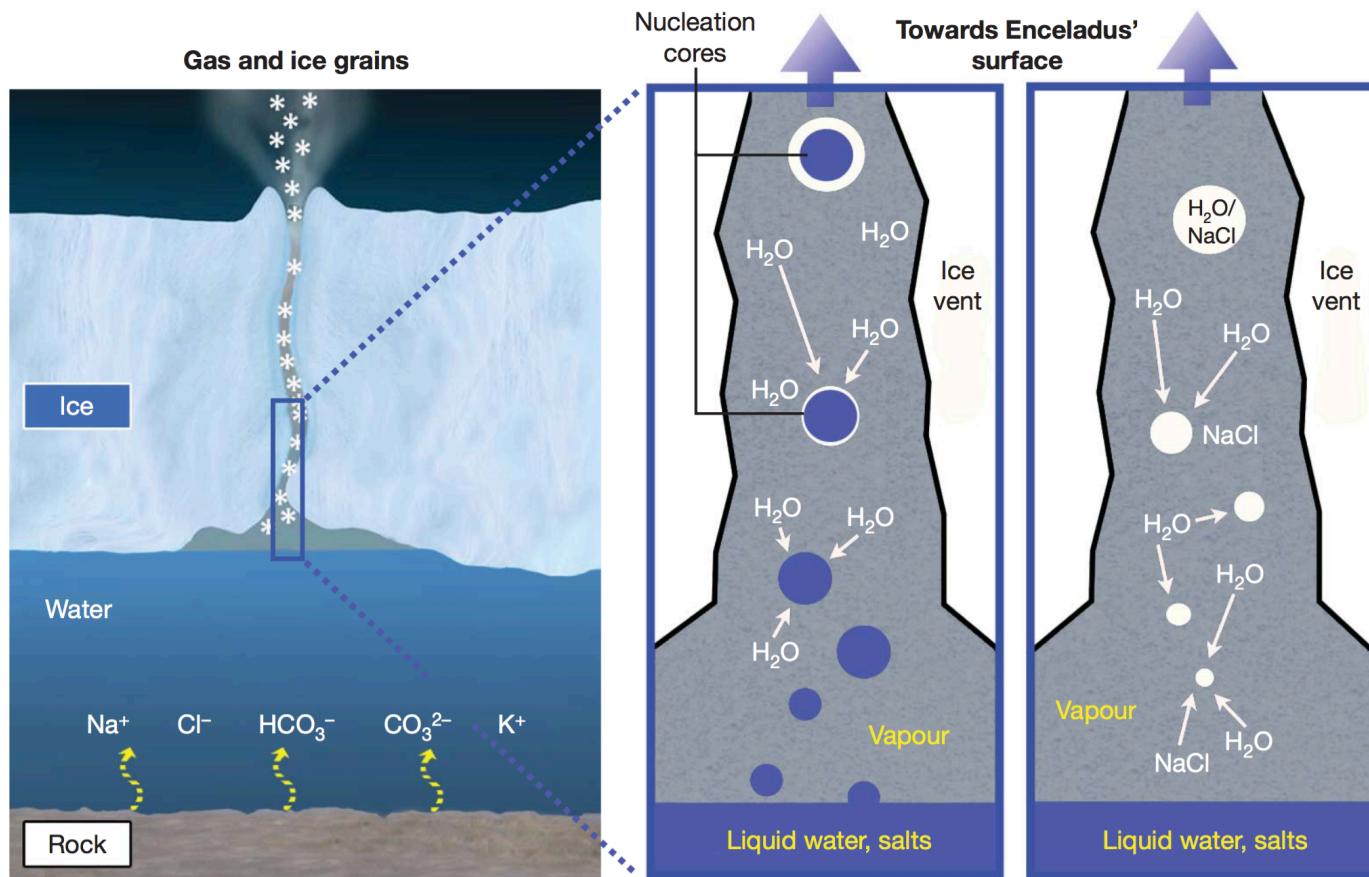
An epic photobomb



An epic photobomb

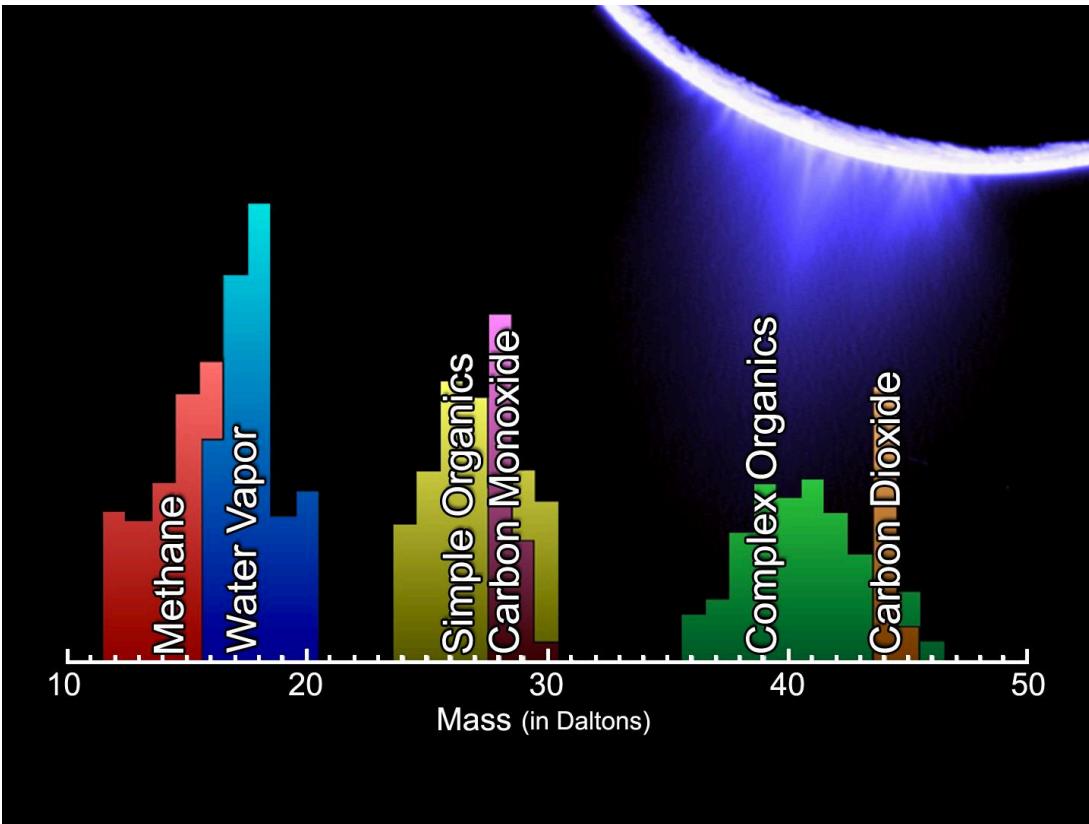


Cryovolcanic plume



The plume expresses the subsurface ocean into space.

Plume composition –Vapor



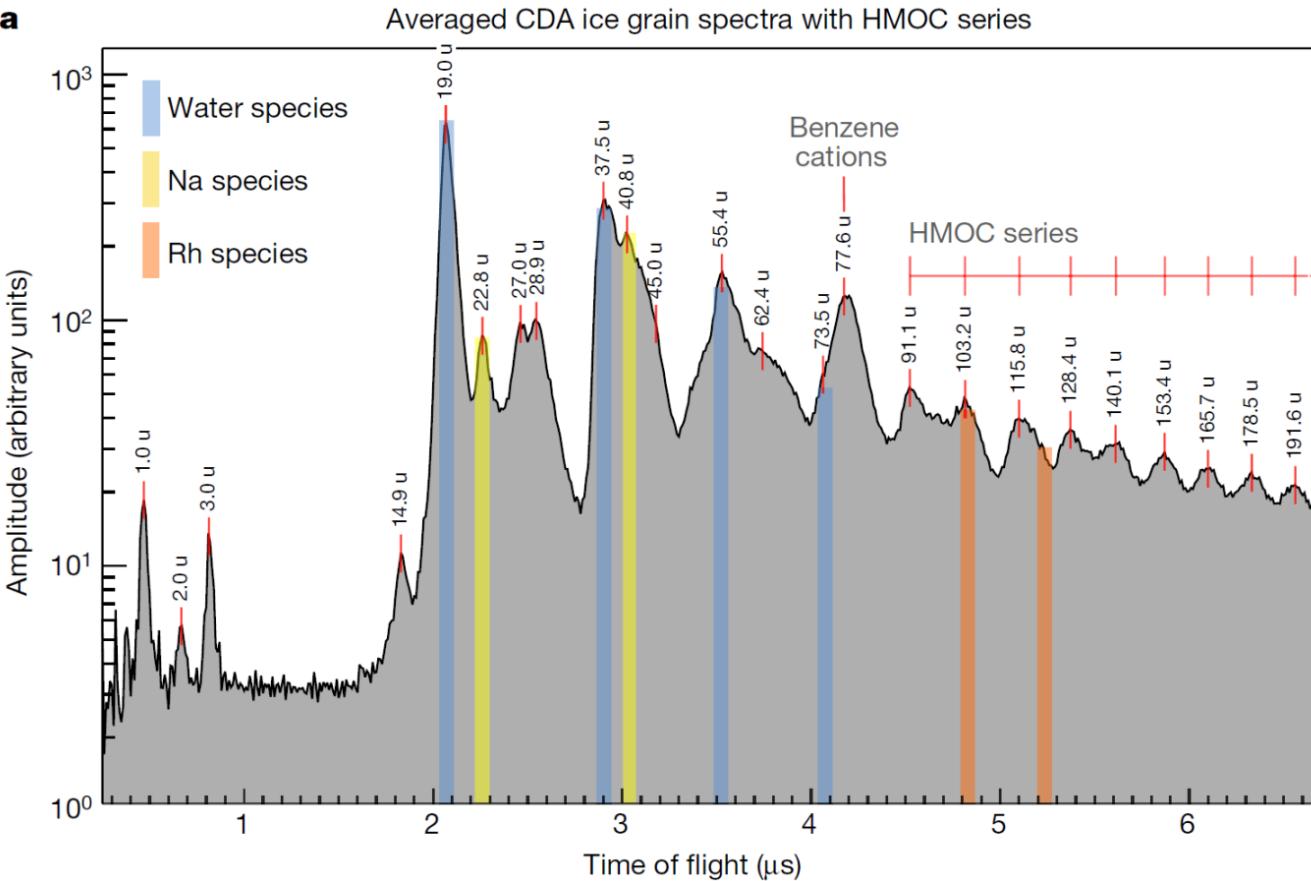
Gas component

- H_2O , CO_2 , CH_4 , NH_3 , and H_2
- Heavier hydrocarbons
- Simple and complex organics

Constituent	Mixing ratio (%)
H_2O	96 to 99
CO_2	0.3 to 0.8
CH_4	0.1 to 0.3
NH_3	0.4 to 1.3
H_2	0.4 to 1.4

Plume composition –Solid

a



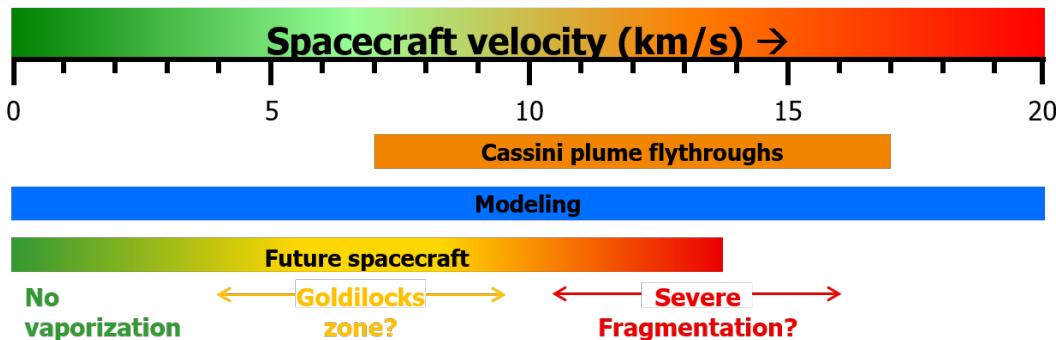
Grain component

- Water-ice
- Salts (mostly NaCl)
- High mass organic cations (HMOC)

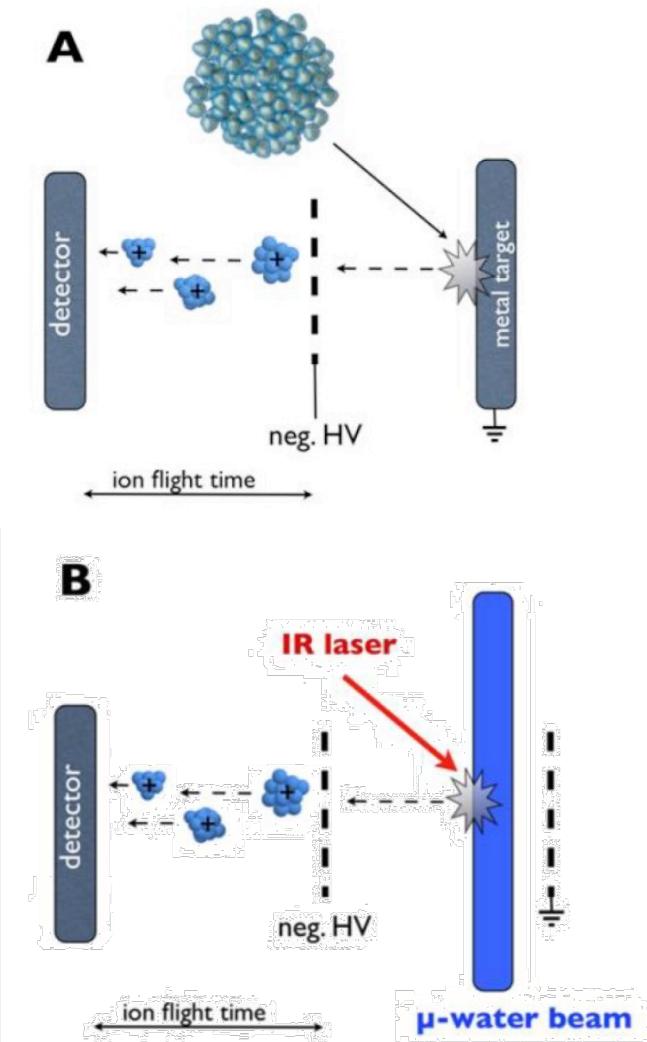
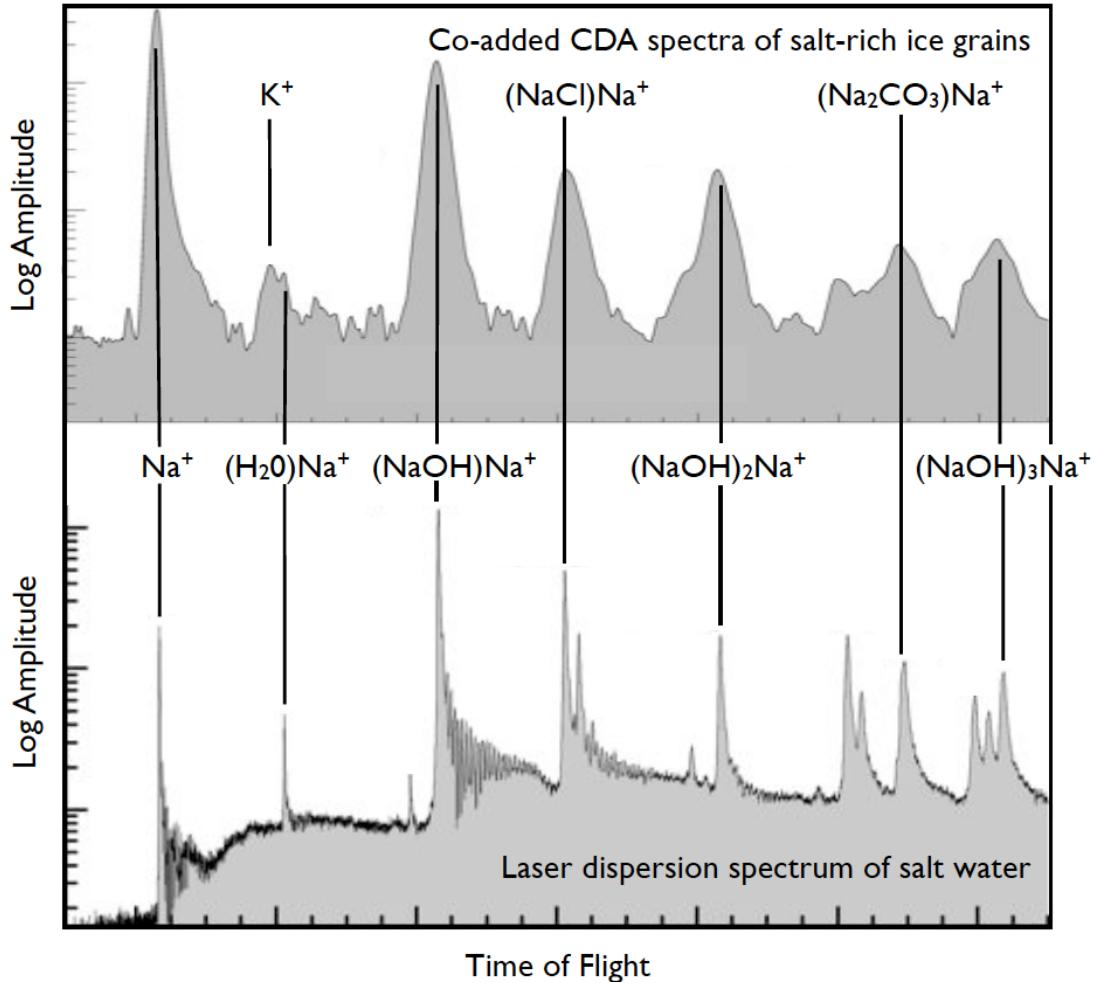
Average grain size:
0.6 μm

The trouble with plumes...

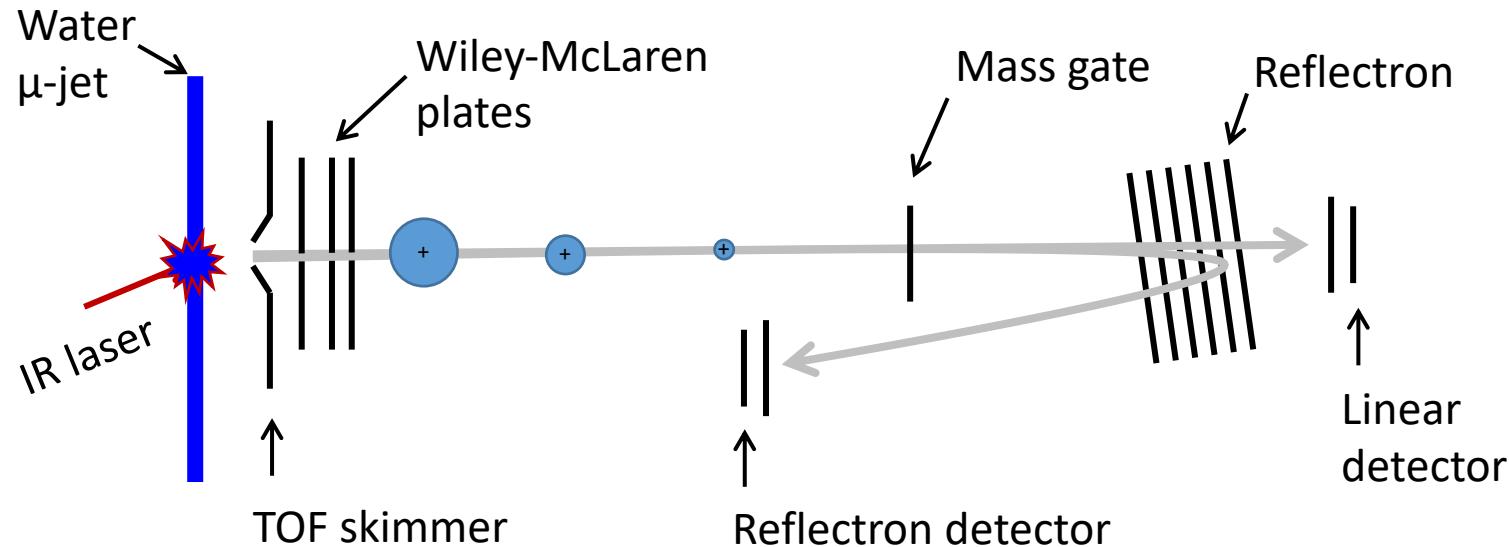
- Hypervelocity sampling (>1 km/s)
- Will cause fragmentation but to what extent?
- Test with laboratory analogs
- Simulate hypervelocity collisions of bare molecules and hydrated clusters



Reproducing CDA's Data

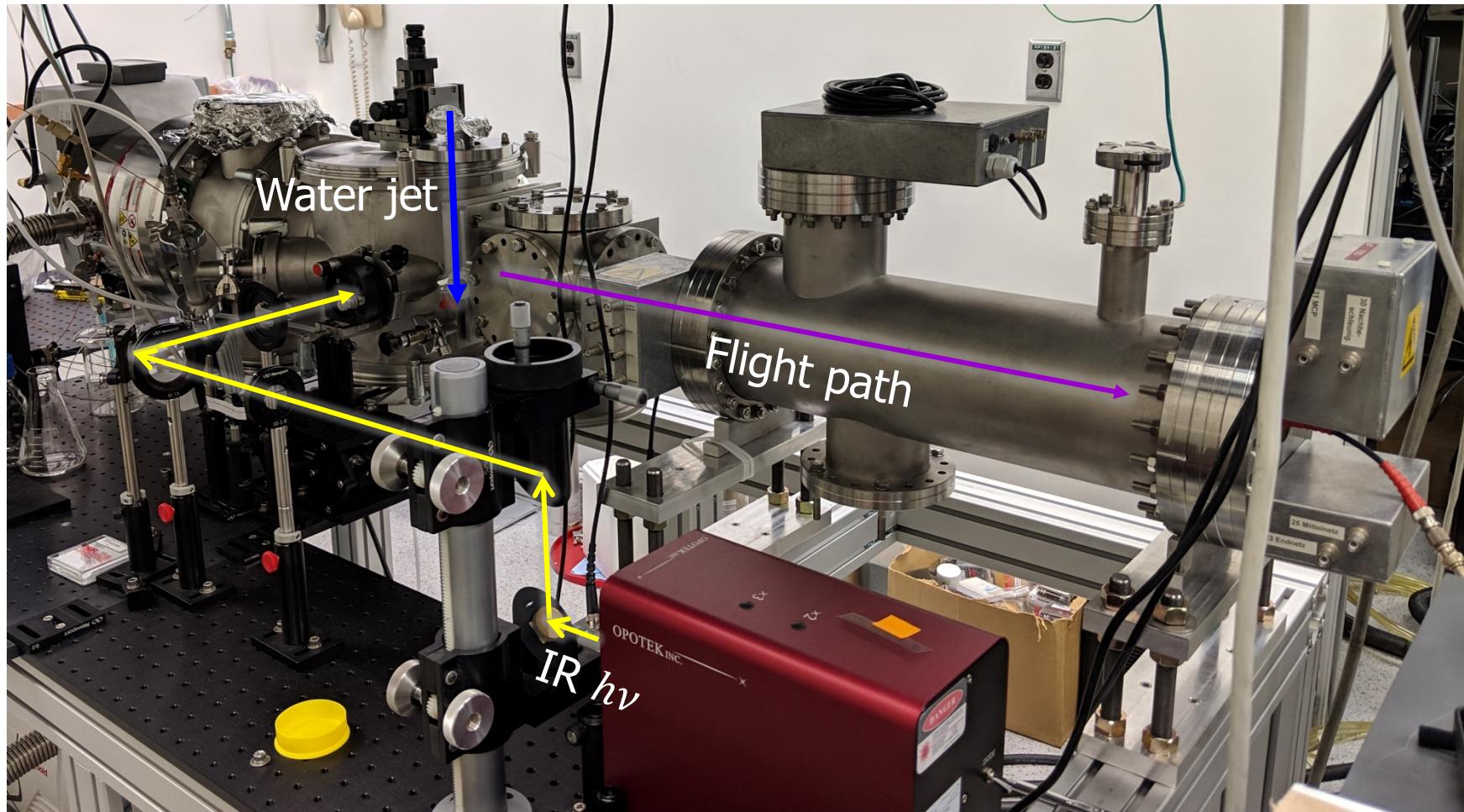


Hypervelocity Ice Grain System

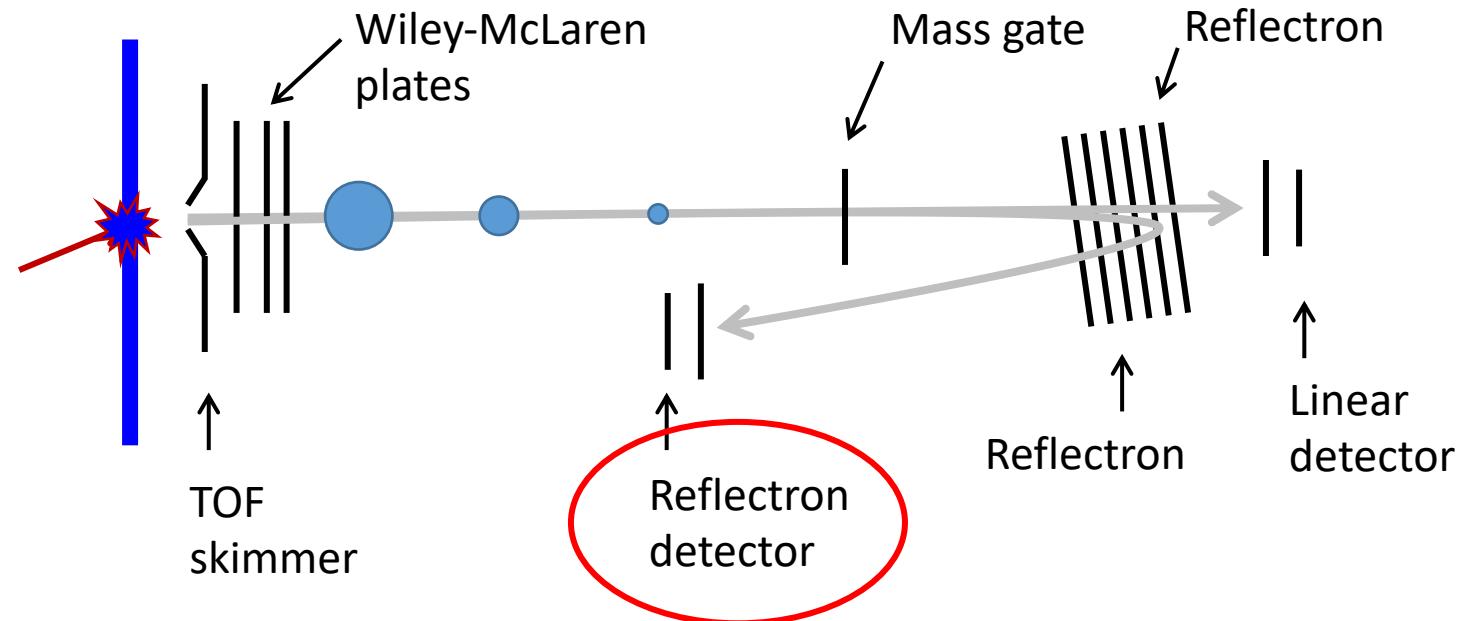


- Generates ice grains, hydrated clusters, and bare ions that travel at hypervelocity
 - Laser-induced ion desorption (LID) source
 - Time-of-flight (TOF) mass spectrometry
 - Reflectron-TOF (rTOF)
 - Linear-TOF (lTOF)
- Currently characterizing LID products and the beam

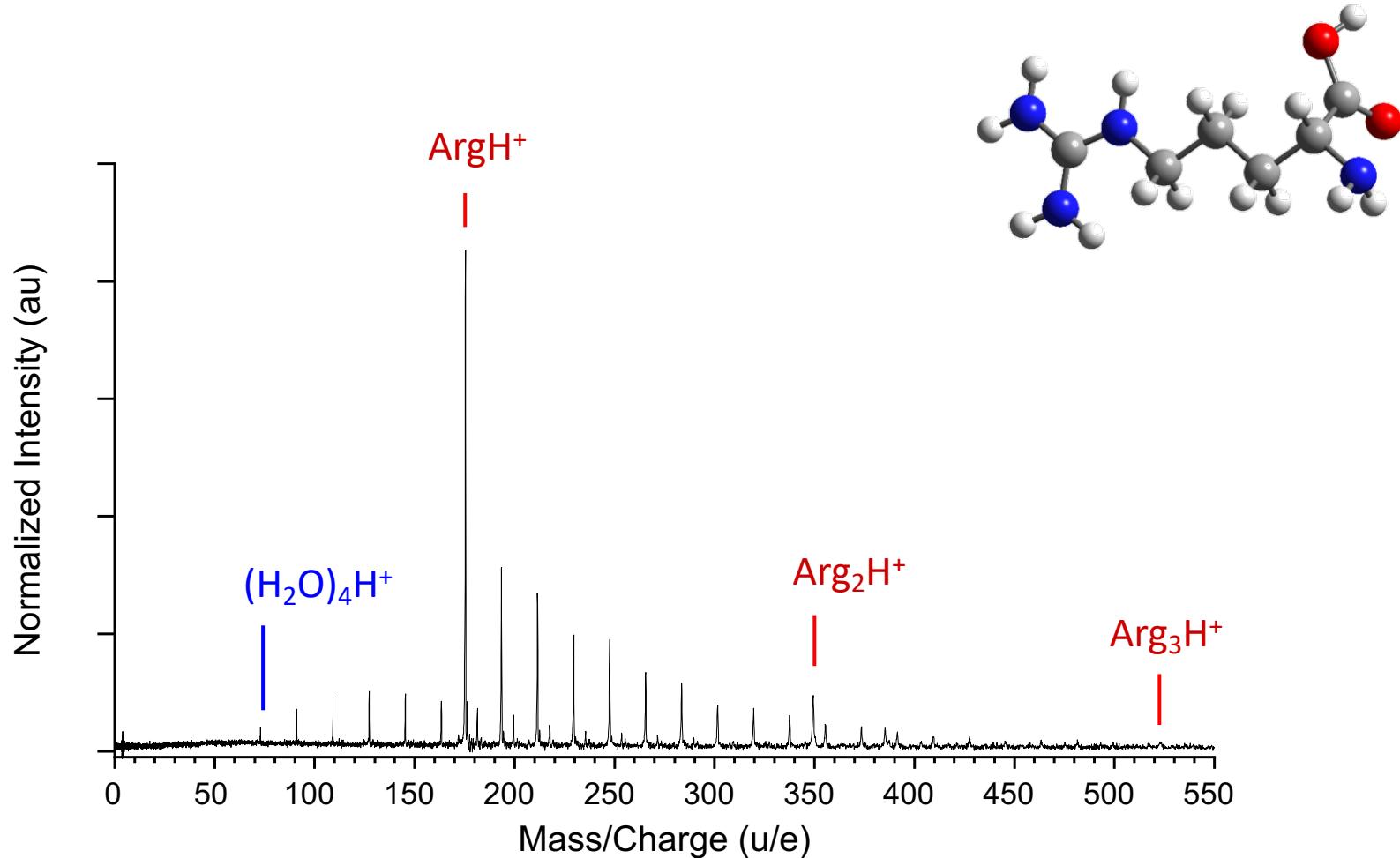
Hypervelocity Ice Grain System



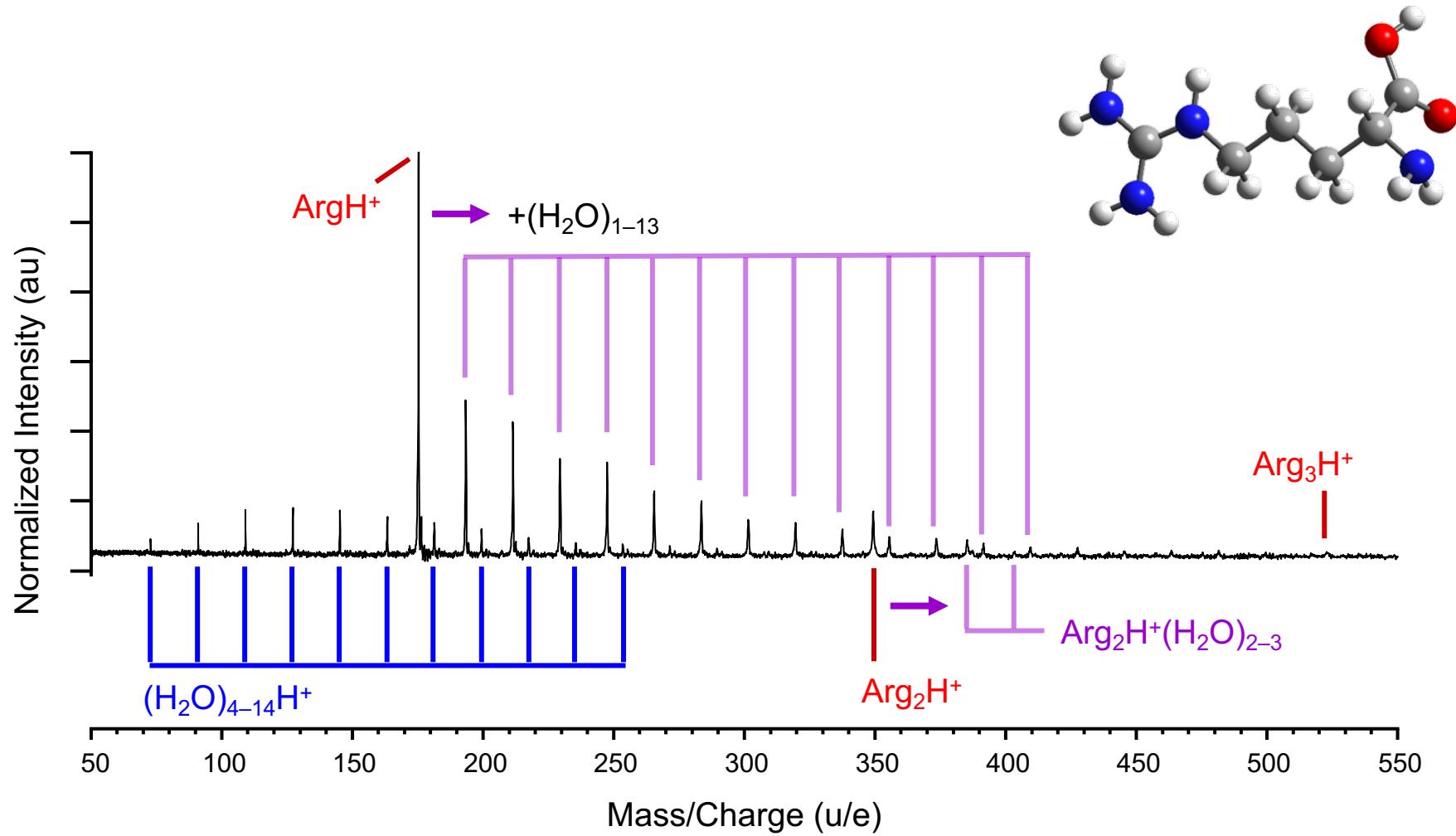
Hypervelocity Ice Grain System



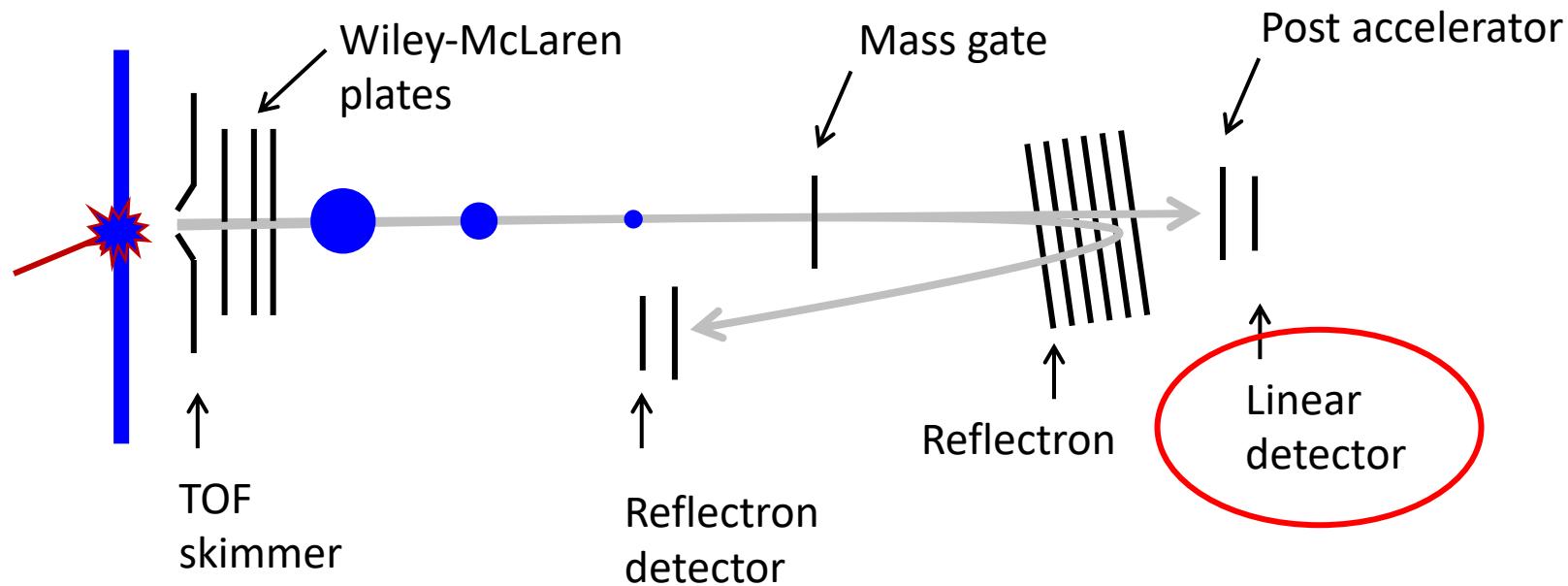
rTOF – 10 mM Arginine



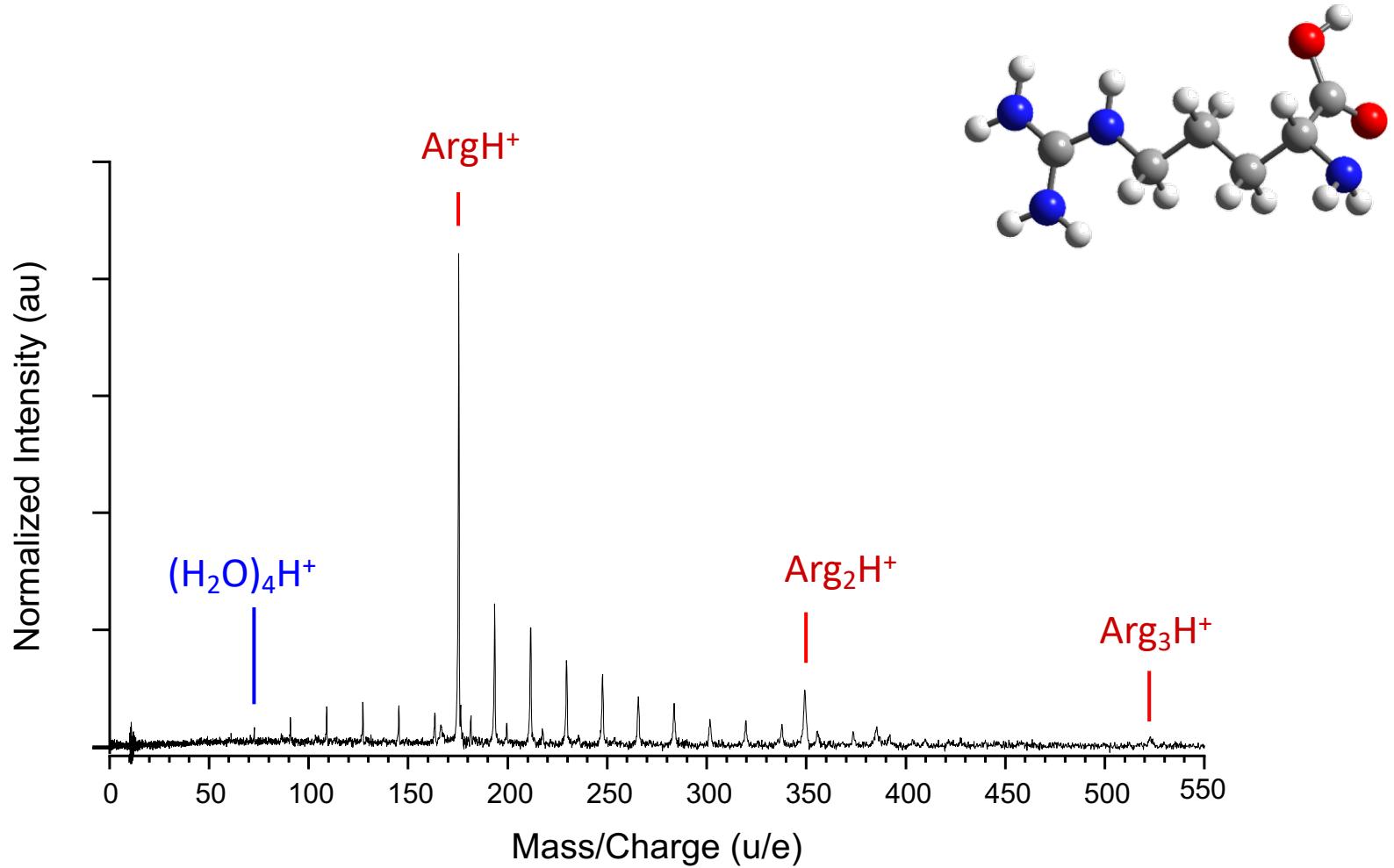
A closer look –rTOF Arg



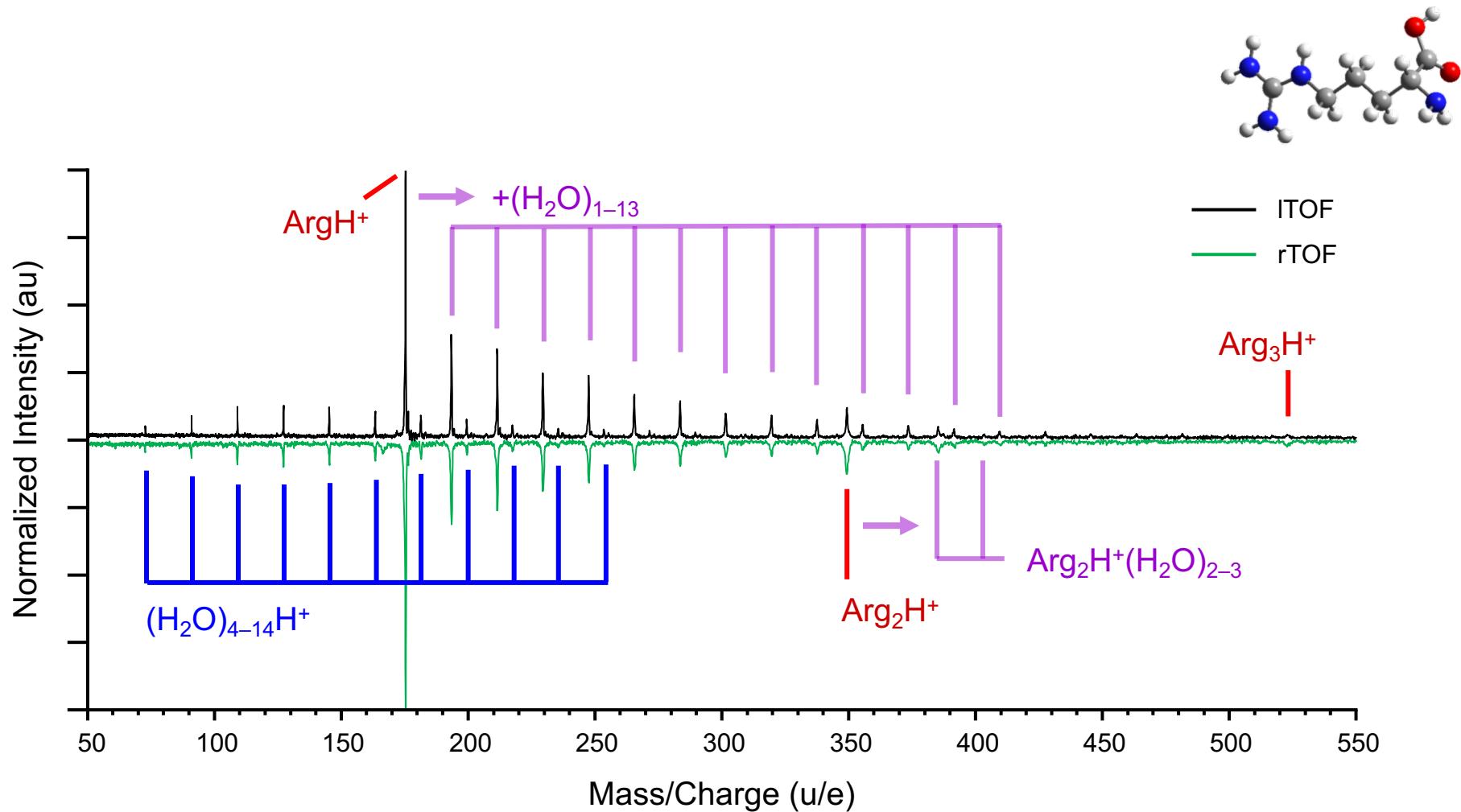
Hypervelocity Ice Grain System



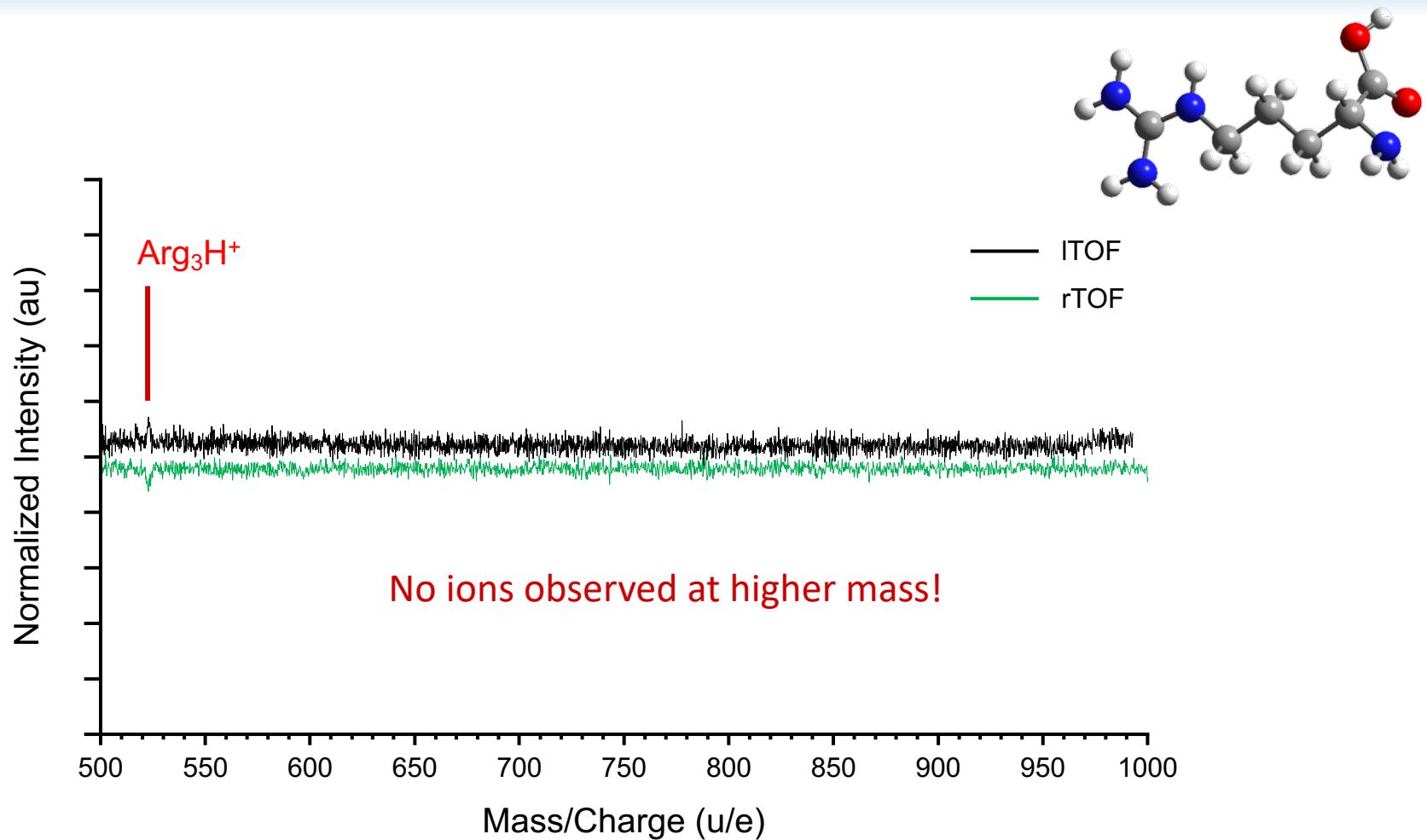
ITOF - 10mM Arginine



rTOF vs ITOF – 10mM Arginine



rTOF vs ITOF – 10mM Arginine



Ion velocities

Ion	m/z (amu)	Velocity (m/s)
(H ₂ O) ₃ H ⁺	55	1.57x10 ⁵
GlyH ⁺	76	1.33x10 ⁵
ArgH ⁺	175	8.78x10 ⁴
Arg ₂ H ⁺	349	6.21x10 ⁴
1 nm H ₂ O grain	2517	2.32x10 ⁴
1 μm H ₂ O grain	3.14x10 ¹¹	2.07

$$KE = \frac{1}{2}mv^2$$

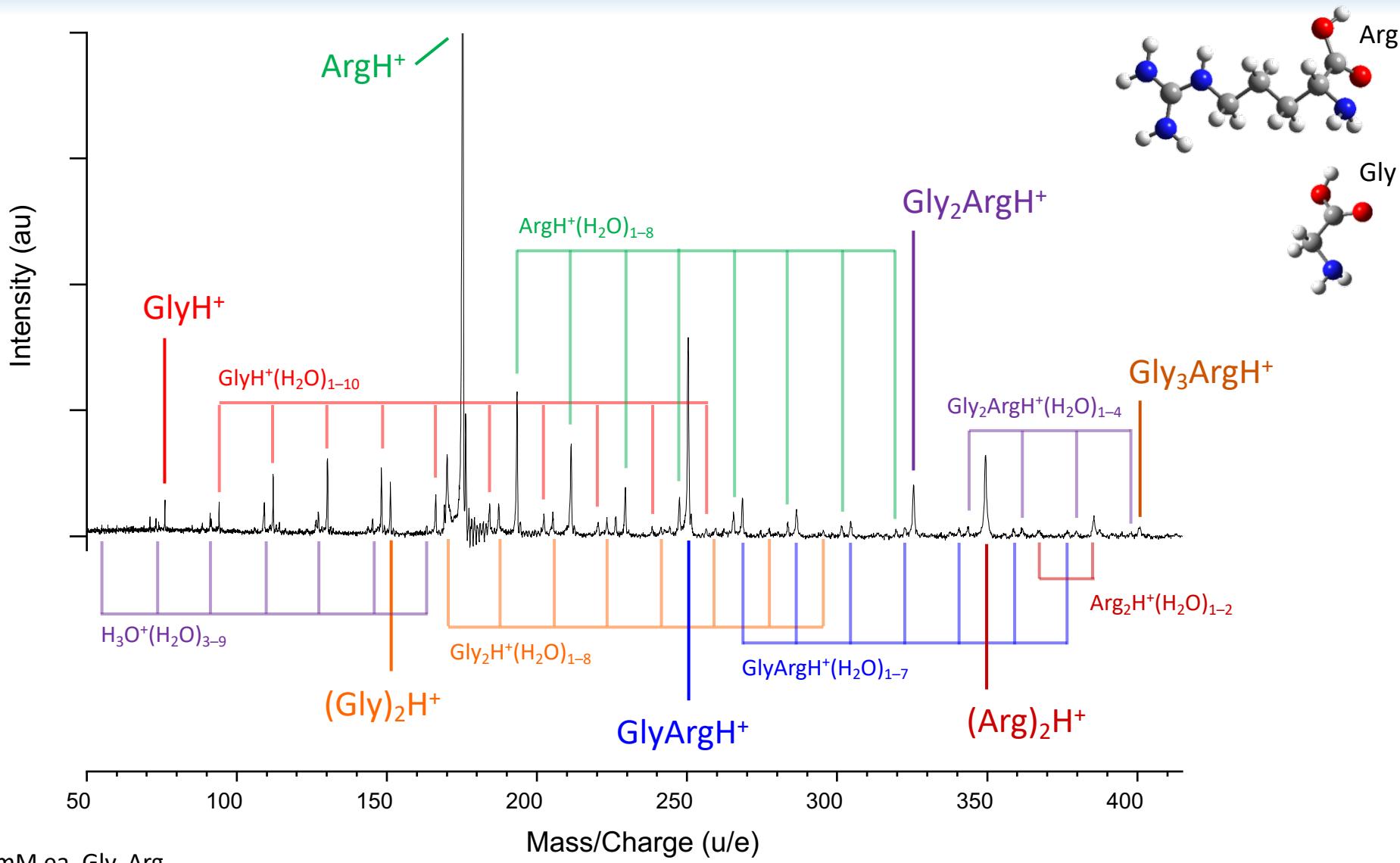


$$\left(\frac{2KE}{m}\right)^{1/2} = v$$

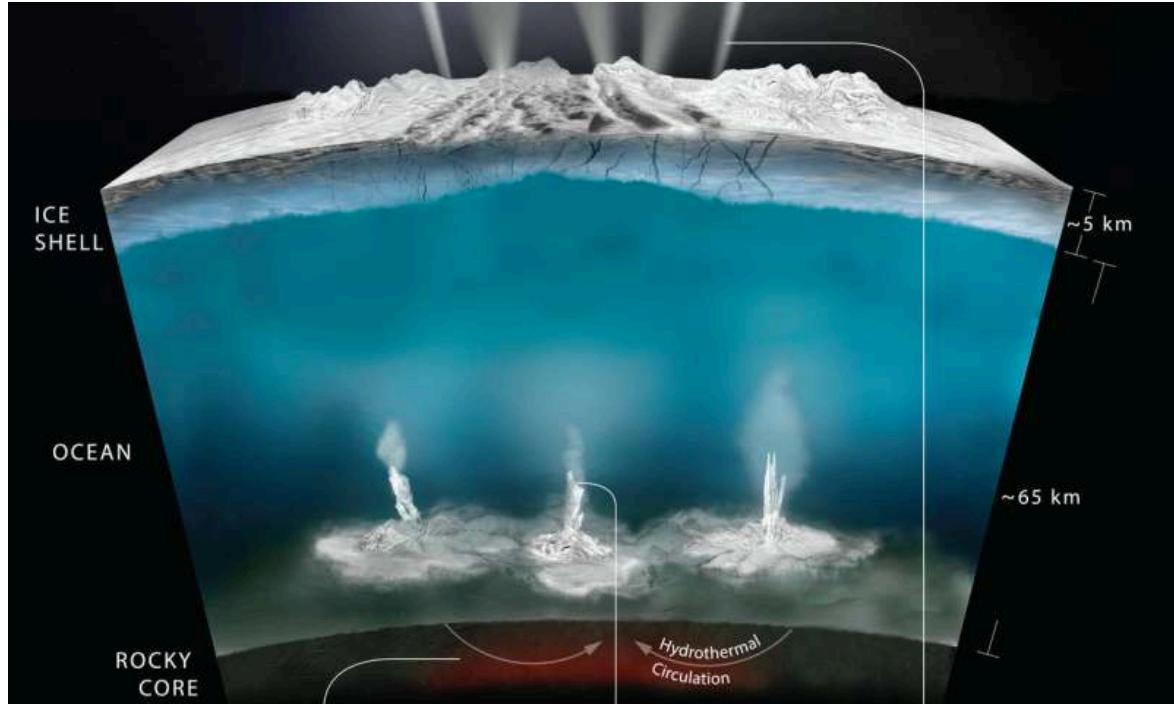
Assumptions:

- KE_{ion} = 7 keV
- Charge = 1+

Glycine/Arginine mixture

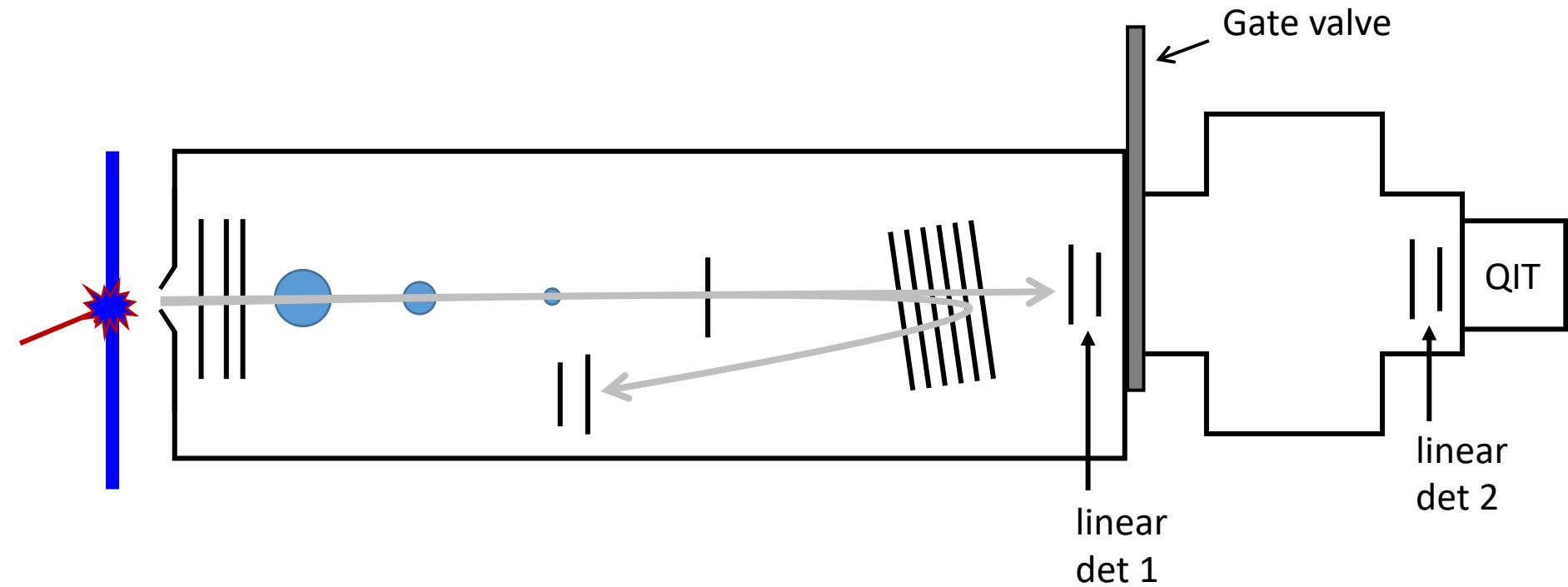


Upcoming experiments



- Enceladus brines
 - NaCl, KCl
- Enceladus pH's (8.5-9)
 - NaHCO₃, Na₂CO₃
- Amino acid mixtures
- Fatty acids
- Polypeptides
- Anion distributions

Upcoming modifications



These mods will enable instruments to be coupled directly to HIGS for testing and validation

Conclusions

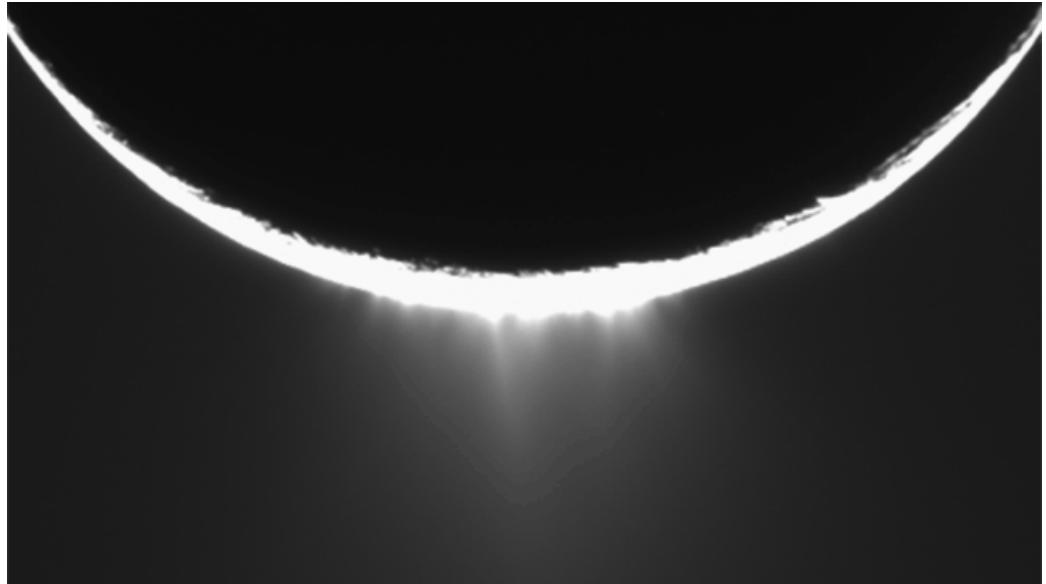


- Lab-based analogs to hypervelocity ice grains
- Enables instrument and methodology validation
- Enables and eases mass spectral analysis of Enceladus' plume

Acknowledgements

Hypervelocity Sampling Team:

Morgan Cable
Jonathan Lunine
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Morgan Miller

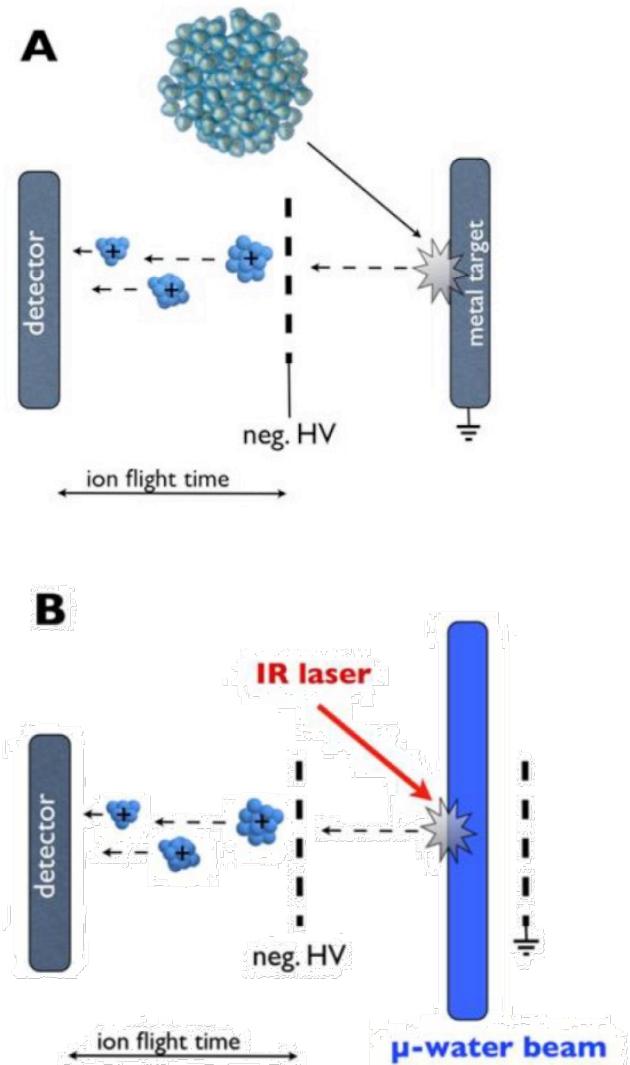
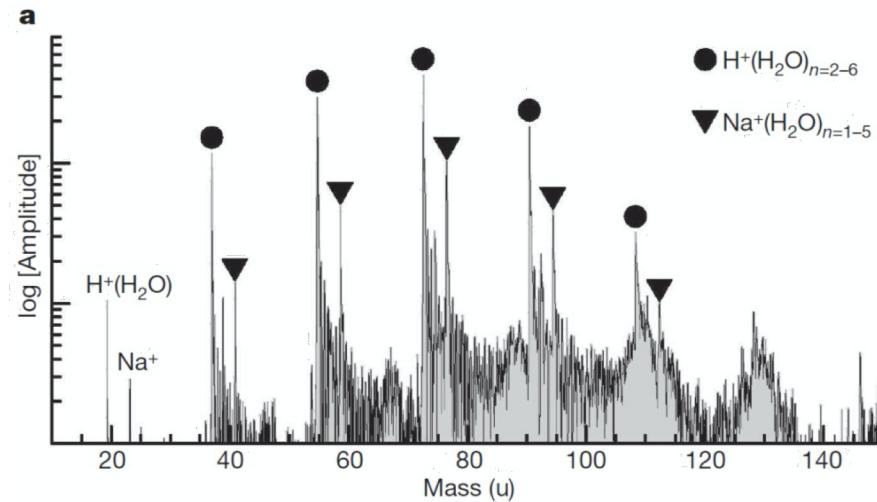
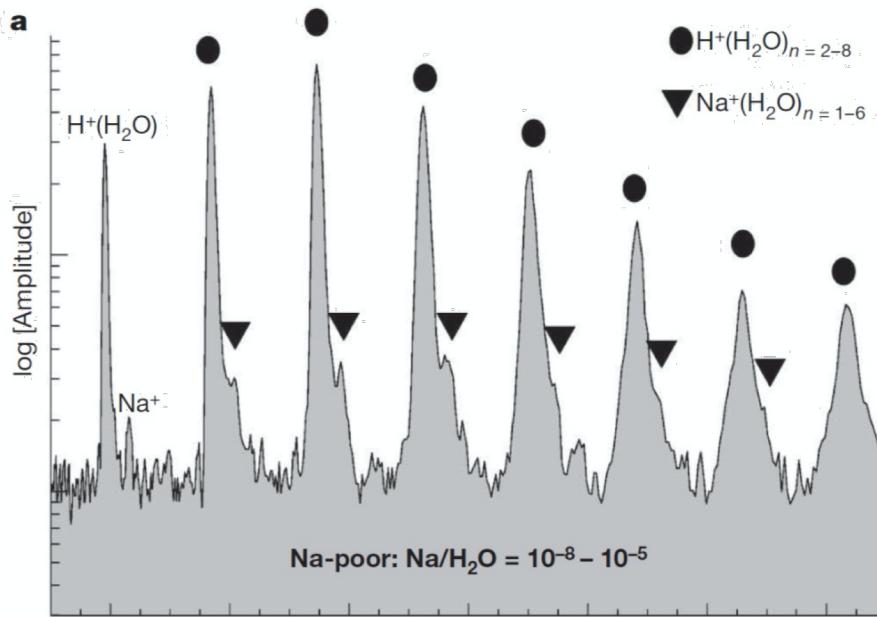


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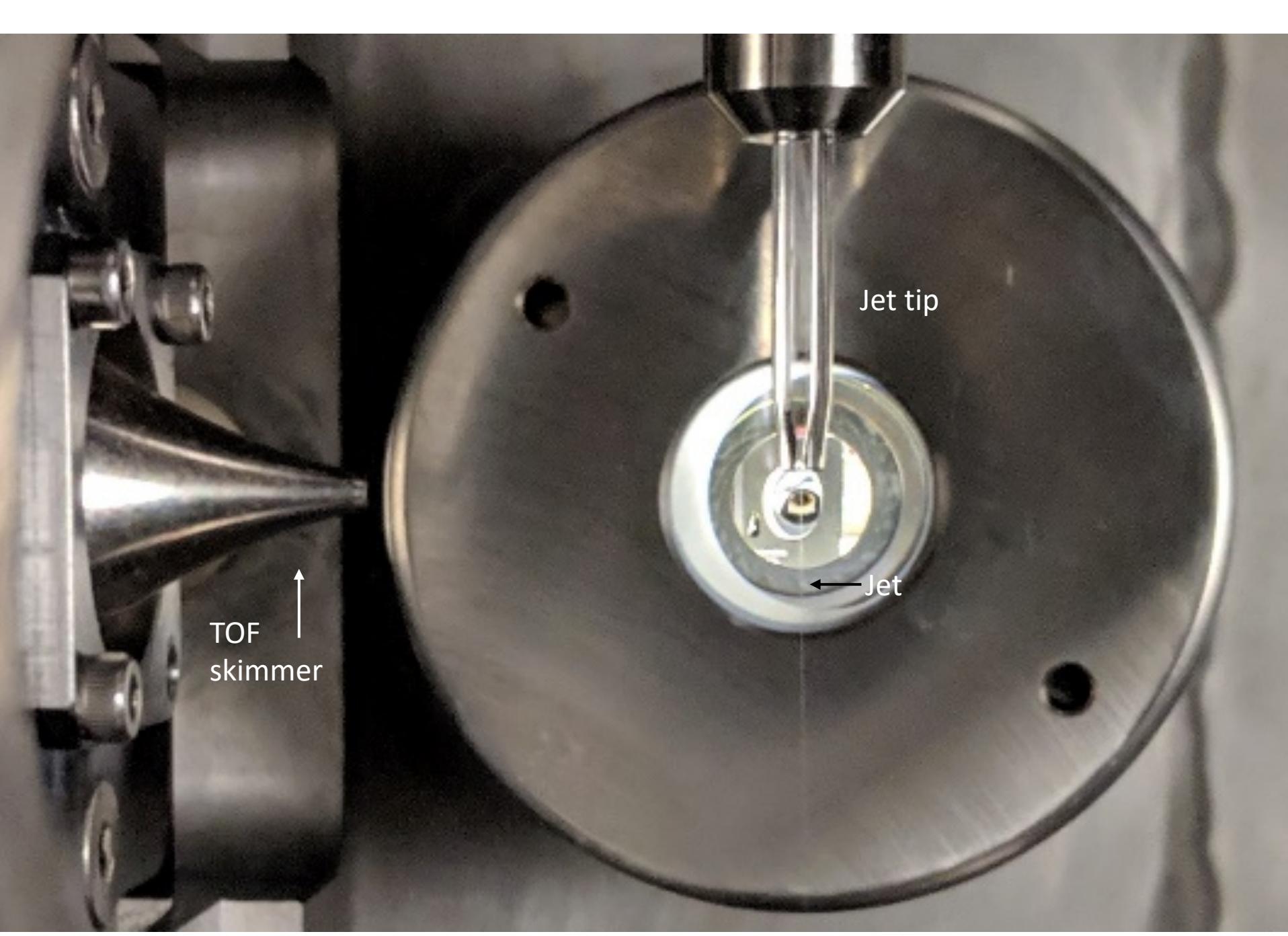


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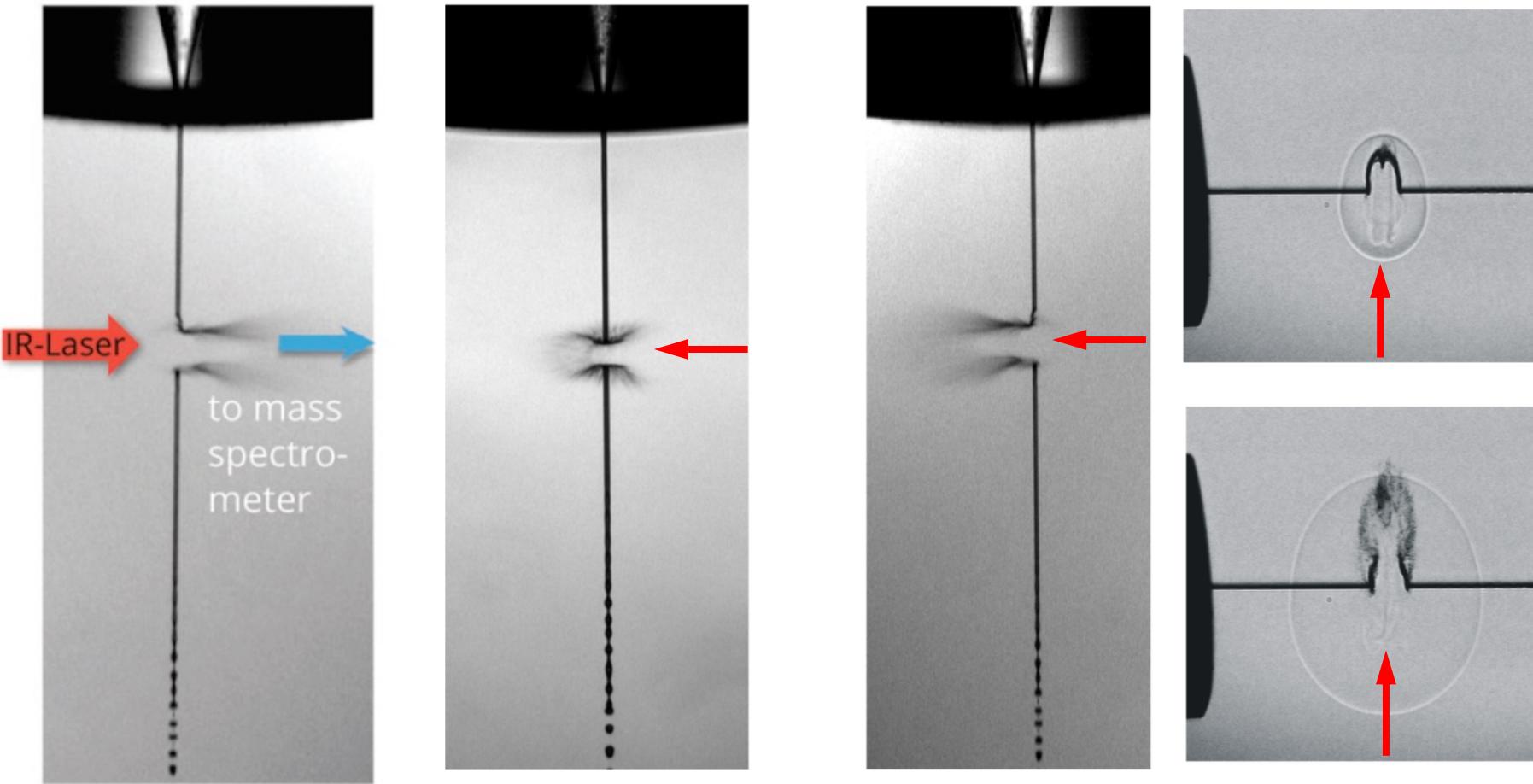
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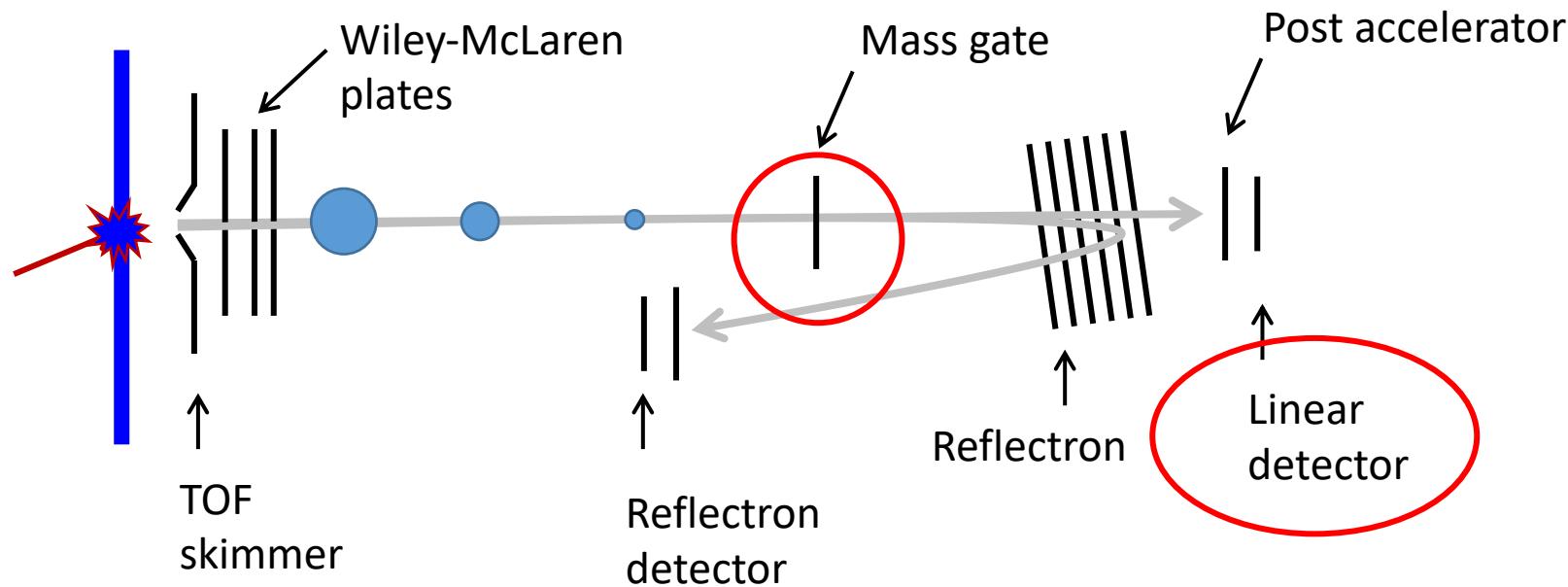
Postberg et al. (2009) Nature, 459, 1098-1101.
Beinsen, (2008)



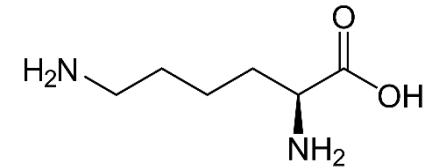
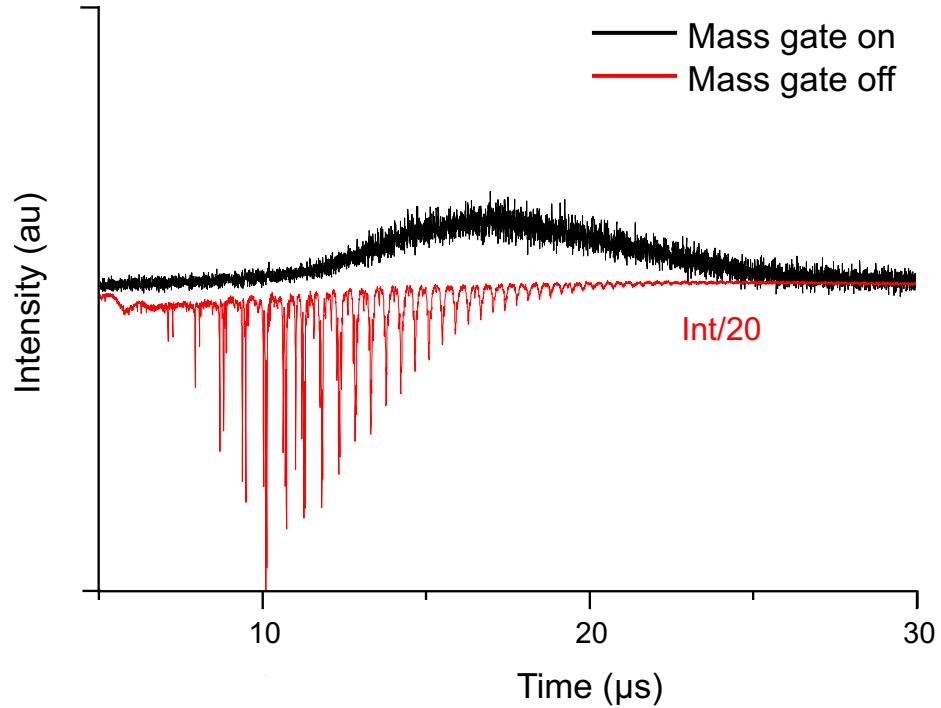
Laser induced desorption



Hypervelocity Ice Grain System

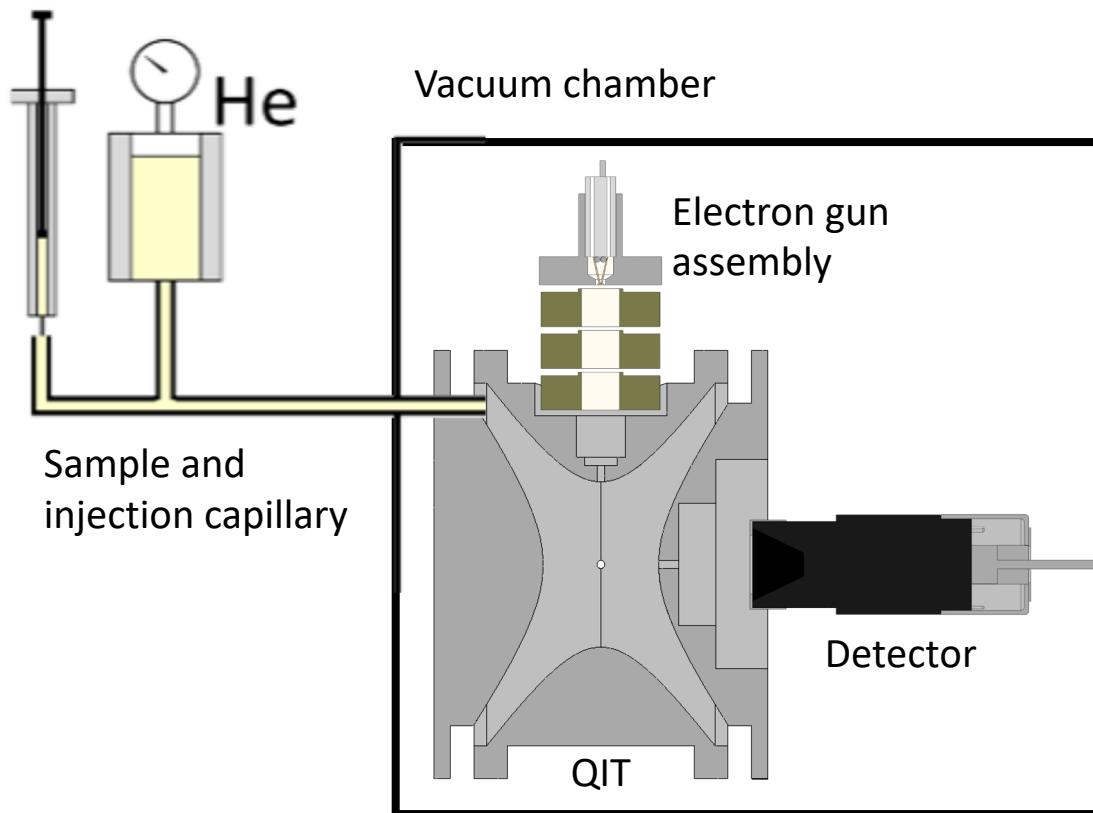


ITOF of neutrals?

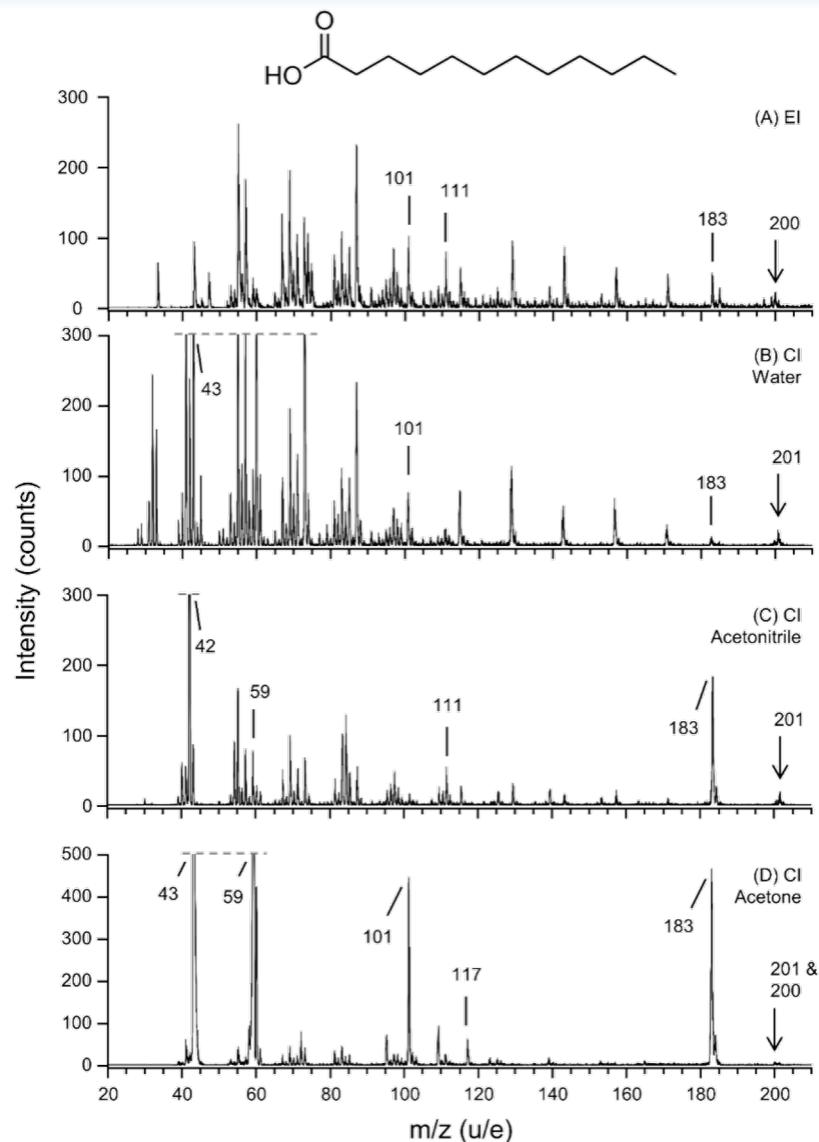


- 10 mM lysine solution
- A broad distribution of neutral speeds

JPL QITMS

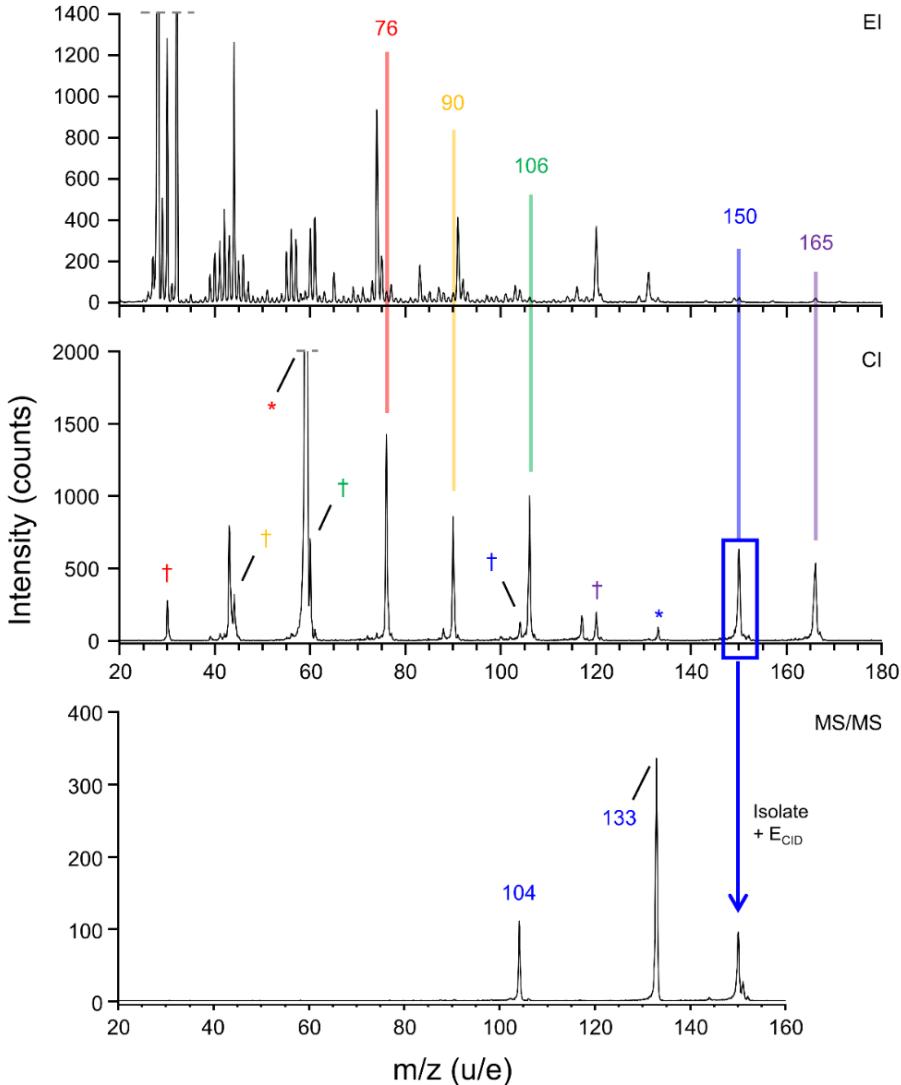


QITMS method development



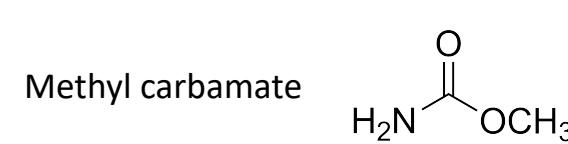
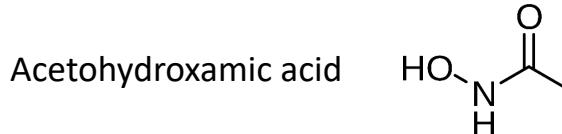
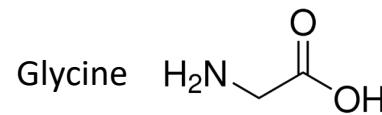
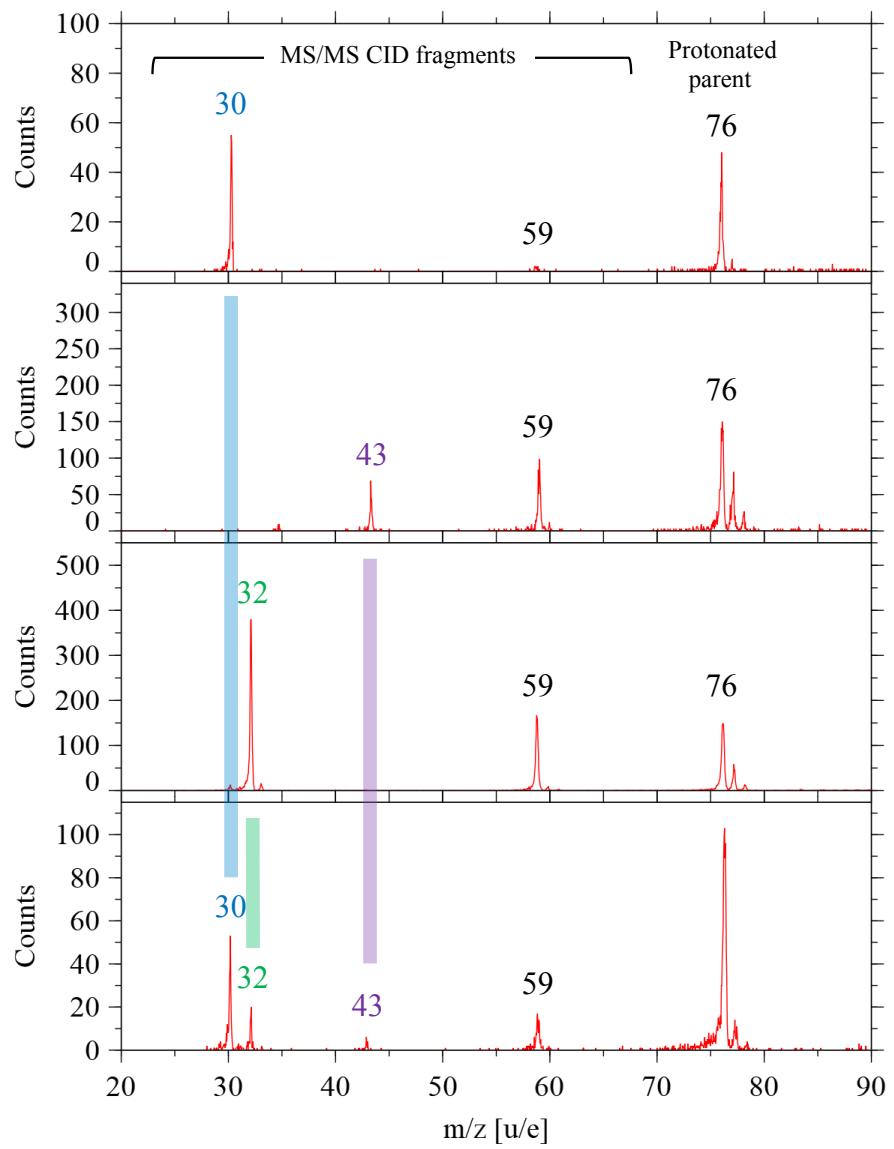
- Electron impact ionization = very messy MS; lowers sensitivity
- Chemical ionization = sometimes just as messy as EI, but not if you choose your CI reagent wisely

CI enables MSⁿ



- CI of a mixture yields easily discernable MS patterns
- However, another way to further ease MS interpretation is to utilize tandem MS
- This makes it very clear which peaks “belong together”
- Also allows us to build a “fingerprint” library for future analyses

Isomer identification



Mixture of all three

Tandem MS can aid in isomer identification

Quantitation

Working on getting
graph for this

- Might talk about this if there is time, but I suspect there isn't
- I can give a shout-out though